From: Edward O. Wilson, *Consilience: The Unity of Knowledge.* London: Abacus, 1998, pp. 119-132

THE MIND

Mind is a stream of conscious and subconscious experience. It is at root the coded representation of sensory impressions and the memory and imagination of sensory impressions. The information composing it is most likely sorted and retrieved by vector coding, which denotes direction and magnitude. For example, a particular taste might be partly classified by the combined activity of nerve cells responding to different degrees of sweetness, saltiness, and sourness. If the brain were designed to distinguish ten increments in each of these taste dimensions, the coding could discriminate 10 X 10 X 10, or 1,000 substances.

Consciousness consists of the parallel processing of vast numbers of such coding networks. Many are linked by the synchronized firing of the nerve cells at forty cycles per second, allowing the simultaneous internal mapping of multiple sensory impressions. Some of the impressions are real, fed by ongoing stimulation from outside the nervous system, while others are recalled from the memory banks of the cortex. All together they create scenarios that flow realistically back and forth through time. The scenarios are a virtual reality. They can either closely match pieces of the external world or depart indefinitely far from it. They re-create the past and cast up alternative futures that serve as choices for future thought and bodily action. The scenarios comprise dense and finely differentiated patterns in the brain circuits. When fully open to input from the outside, they correspond well to all the parts of the environment, including activity of the body parts, monitored by the sense organs.

Who or what within the brain monitors all this activity? No one. Nothing. The scenarios are not seen by some other part of the brain. They just are. Consciousness is the virtual world composed by the scenarios. There is not even a Cartesian theater, to use Daniel Dennett's dismissive phrase, no single locus of the brain where the scenarios are played out in coherent form. Instead, there are interlacing patterns of neural activity within and among particular sites throughout the forebrain, from cerebral cortex to other specialized centers of cognition such as the thalamus, amygdala, and

hippocampus. There is no single stream of consciousness in which all information is brought together by an executive ego. There are instead multiple streams of activity, some of which contribute momentarily to conscious thought and then phase out. Consciousness is the massive coupled aggregates of such participating circuits. The mind is a self-organizing republic of scenarios that individually germinate, grow, evolve, disappear, and occasionally linger to spawn additional thought and physical activity.

The neural circuits do not turn on and off like parts of an electrical grid. In many sectors of the forebrain at least, they are arranged in parallel relays stepping from one neuron level to the next, integrating more and more coded information with each step. The energy of light striking the retina, to expand the example I gave earlier, is transduced into patterns of neuron firing. The patterns are relayed through a sequence of intermediate neuron systems out of the retinal fields through the lateral geniculate nuclei of the thalamus back to the primary visual cortex at the rear of the brain. Cells in the visual cortex fed by the integrated stimuli sum up the information from different parts of the retina. They recognize and by their own pattern of firing specify spots or lines. Further systems of these higher-order cells integrate the information from multiple feeder cells to map the shape and movement of objects. In ways still not understood, this pattern is coupled with simultaneous input from other parts of the brain to create the full scenarios of consciousness. The biologist S. J. Singer has drily expressed the matter thus: I link, therefore I am.

Because just to generate consciousness requires an astronomically large population of cells, the brain is sharply limited in its capacity to create and hold complex moving imagery. A key measure of that capacity lies in the distinction made by psychologists between short-term and long-term memory. Short-term memory is the ready state of the conscious mind. It composes all of the current and remembered parts of the virtual scenarios. It can handle only about seven words or other symbols simultaneously. The brain takes about one second to scan these symbols fully, and it forgets most of the information within thirty seconds. Long-term memory takes much longer to acquire, but it has an almost unlimited capacity, and a large fraction of it is retained for life. By spreading activation, the conscious mind summons information from the store of long-term memory and holds it for a brief interval in short-term memory. During this time it processes the

information, at a rate of about one symbol per 25 milliseconds, while scenarios arising from the information compete for dominance.

Long-term memory recalls specific events by drawing particular persons, objects, and actions into the conscious mind through a time sequence. For example, it easily re-creates an Olympic moment: the lighting of the torch, a running athlete, the cheering of the crowd. It also re-creates not just moving images and sound but *meaning* in the form of linked concepts simultaneously experienced. Fire is connected to hot, red, dangerous, cooked, the passion of sex, and the creative act, and on through multitudinous hypertext pathways selected by context, sometimes building new associations in memory for future recall. The concepts are the nodes or reference points in long-term memory. Many are labelled by words in ordinary language, but others are not. Recall of images from the long-term banks with little or no linkage is just memory. Recall with linkages, and especially when tinged by the resonance of emotional circuits, is remembrance.

The capacity for remembrance by the manipulation of symbols is a transcendent achievement for an organic machine. It has authored all of culture. But it still falls far short of the demands placed by the body on the nervous system. Hundreds of organs must be regulated continuously and precisely; any serious perturbation is followed by illness or death. A heart forgetful for ten seconds can drop you like a stone. The proper functioning of the organs is under the control of hard-wired autopilots in the brain and spinal cord, whose neuron circuits are our inheritance from hundreds of millions of years of vertebrate evolution prior to the origin of human consciousness. The autopilot circuits are shorter and simpler than those of the higher cerebral centers and only marginally communicate with them. Only by intense meditative training can they occasionally be brought under conscious control. ….

Much of the input to the brain does not come from the outside world but from internal body sensors that monitor the state of respiration, heartbeat, digestion, and other physiological activities. The flood of “gut feelings” that results is blended with rational thought, feeding it, and being fed by it through reflexes of internal organs and neurohormonal loops.

As the scenarios of consciousness fly by, driven by stimuli and drawing upon memories of prior scenarios, they are weighed and modified by emotion. What is emotion? It is the modification of neural activity that animates and focuses mental activity. It is created by physiological activity that selects certain streams of information over others, shifting the body and mind to higher or lower degrees of activity, agitating the circuits that create scenarios, and selecting ones that end in certain ways. The winning scenarios are those that match goals pre-programmed by instinct and the satisfaction of prior experience. Current experience and memory continually perturb the states of mind and body. By thought and action the states are then moved backward to the original condition or forward to conditions conceived in new scenarios. ….

What we call *meaning* is the linkage among the neural networks created by the spreading excitation that enlarges imagery and engages emotion. The competitive selection among scenarios is what we call *decision making.* The outcome, in terms of the match of the winning scenario to instinctive or learned favourable states, sets the kind and intensity of subsequent emotion. The persistent form and intensity of emotions is called *mood.* The ability of the brain to generate novel scenarios and settle on the most effective among them is called *creativity*. The persistent production of scenarios lacking reality and survival value is called *insanity*. ….

I will next describe the deeper problems that must be resolved before the physical basis of mind can be said to be truly solved. The one universally judged to be the most difficult of all is the nature of subjective experience. The Australian philosopher David Chalmers recently put the matter in perspective by contrasting the "easy problem" of general consciousness with the "hard problem" of subjective experience. In the first group (easy, I suppose, in the sense that Mont Blanc is more readily climbed in beachwear than Everest) are the classical problems of mind research: how the brain responds to sensory stimuli, how it incorporates information into patterns, and how it converts the patterns into words. Each of these steps of cognition are the subjects of vigorous contemporary research.

The hard problem is more elusive: how physical processes in the brain addressed in the easy problem give rise to subjective feeling. What exactly does it mean when we say *we experience* a color such as red or blue? Or experience, in Chalmer's words, "the ineffable sound of a distant oboe, the

agony of an intense pain, the sparkle of happiness or the meditative quality of a moment lost in thought. All are part of what I am calling consciousness. It is these phenomena that compose the real mystery of the mind."

An imaginary experiment proposed by the philosopher Frank Jackson in 1983 illustrates the supposed unattainability of subjective thought by the natural sciences. Consider a neurobiologist two centuries hence who understands all the physics of color and all the brain's circuitry giving rise to color vision. But the scientist (call her Mary) has never experienced color; she has been cloistered all her life in a black-and-white room. She does not know what it is like for another person to see red or blue; she cannot imagine how they feel about color. According to Jackson and Chalmers, it follows that there are qualities of conscious experience that cannot be deduced from knowledge of the physical functioning of the brain.

Although it is the nature of philosophers to imagine impasses and expatiate upon them at book length with schoolmasterish dedication, the hard problem is conceptually easy to solve. What material description might explain subjective experience? The answer must begin by conceding that Mary cannot know what it feels like to see color. The chromatic nuances of a westering sun are not hers to enjoy. And for the same reason she and all her fellow human beings *a fortiori* cannot know how a honeybee feels when it senses magnetism or what an electric fish thinks as it orients by an electric field. We can translate the energies of magnetism and electricity into sight and sound, the sensory modalities we biologically possess. We can read the active neural circuits of bees and fish by scanning their sense organs and brains. But we cannot feel as they do – ever. Even the most imaginative and expert observers cannot think as animals, however they may wish or deceive themselves otherwise.

But incapacity is not the point. The distinction that illuminates subjective experience lies elsewhere, in the respective roles of science and art. Science perceives who can feel blue and other sensations and who cannot feel them, and explains why that difference exists. Art in contrast transmits feelings among persons of the same capacity. In other words, science explains feeling, while art transmits it. The majority of human beings, unlike Mary, see a full color spectrum, and they feel its productions in reverberating pathways through the forebrain. The basic patterns are demonstrably similar across all color-sighted human beings. Variations exist, owing to

remembrances that arise from the personal memories and cultural biases of different people. But in theory these variations can also be read in the patterns of their brain activity. The physical explanations derived from the patterns would be understandable to Mary the confined scientist. She might say, "Yes, that is the wavelength span classified by others as blue, and there is the pattern of neural activity by which it is recognised and named." The explanations would be equally clear to bee and fish scientists if their species could somehow be raised to human levels of intelligence.

Art is the means by which people of similar cognition reach out to others in order to transmit feelings. But how can we know for sure that art communicates this way with accuracy, that people really, truly *feel* the same in the presence of art? We know it intuitively by the sheer weight of our cumulative responses through the many media of art. We know it by detailed verbal descriptions of emotions, by critical analyses, and in fact through data from all the vast, nuanced, and interlocking armamentaria of the humanities. That vital role in the sharing of culture is what the humanities are all about. Nevertheless, fundamental new information will come from science by studying the dynamic patterns of the sensory and brain systems during episodes when commonly shared feelings are evoked and experienced through art. ….

An old impasse nonetheless remains: If the mind is bound by the laws of physics, and if it can conceivably be read like calligraphy, how can there be free will? I do not mean free will in the trivial sense, the ability to choose one's thoughts and behaviour free of the will of others and the rest of the world all around. I mean, instead, freedom from the constraints imposes by the physiochemical states of one's own body and mind. In the naturalistic view, free will in this deeper sense is the outcome of competition among the scenarios that compose the conscious mind. The dominant scenarios are those that rouse the emotion circuits and engage them to greatest effect during reverie. They energize and focus the mind as a whole and direct the body in particular courses of action. The self is the entity that seems to make such choices. But what is the self?

The self is not an ineffable being living apart within the brain. Rather, it is the key dramatic character of the scenarios. It must exist, and play on center stage, because the senses are located in the body and the body creates the mind to represent the governance of all conscious actions. The self and

body are therefore inseparably fused. The self, despite the illusion of its independence created in the scenarios, cannot exist apart from the body, and the body cannot survive for long without the self. ….

The self, an actor in a perpetually changing drama, lacks full command of its own actions. It does not make decisions solely by conscious, purely rational choice. Much of the computation in decision making is unconscious – strings dancing the puppet ego. Circuits and determining molecular processes exist outside conscious thought. They consolidate certain memories and delete others, bias connections and analogies, and reinforce the neurohormonal loops that regulate subsequent emotional response. Before the curtain is drawn and the play unfolds, the stage has already been partly set and much of the script written.

The hidden preparation of mental activity gives the illusion of free will. We make decisions for reasons we often sense only vaguely, and seldom if ever understand fully. ….

Free will as a side product of illusion would seem to be free will enough to drive human progress and offer happiness. Shall we leave it at that? No, we cannot. The philosophers won't let us. They will say: Suppose that with the aid of science we knew all the hidden processes in detail. Would it then be correct to claim that the mind of a particular individual is predictable, and therefore truly, fundamentally determined and lacking in free will? We must concede that much in principle, but only in the following, very peculiar sense. If within the interval of a microsecond the active networks composing the thought were known down to every neuron, molecule, and ion, their exact state in the next microsecond might be predicted. But to pursue this line of reasoning into the ordinary realm of conscious thought is futile in pragmatic terms, for this reason: If the operations of a brain are to be seized and mastered, they must also be altered. In addition, the principles of mathematical chaos hold. The body and brain comprise noisy legions of cells, shifting microscopically in discordant patterns that unaided consciousness cannot even begin to imagine. The cells are bombarded every instant by outside stimuli unknowable by human intelligence in advance. Any one of the events can entrain a cascade of microscopic episodes leading to new neural patterns. The computer needed to track the consequences would have to be of stupendous proportions, with operations conceivably far more complex than those of the thinking brain itself. Furthermore,

scenarios of the mind are all but infinite in detail, their content evolving in accordance with the unique history and physiology of the individual. How are we to feed that into a computer?

So there can be no simple determinism of human thought, at least not in obedience to causation in the way physical laws describe the motion of bodies and the atomic assembly of molecules. Because the individual mind cannot be fully known and predicted, the self can go on passionately believing in its own free will. And that is a fortunate circumstance. Confidence in free will is biologically adaptive. Without it the mind, imprisoned by fatalism, would slow and deteriorate. Thus in organismic time and space, in every operational sense that applies to the knowable self, the mind *does* have free will.

Finally, given that conscious experience is a physical and not a supernatural phenomenon, might it be possible to create an artificial human mind? I believe the answer to this philosophically troubling question to be yes in principle, but no in practice, at least not as a prospect for many decades or even centuries to come.